US007527873B2

(12) **United States Patent**
Kumar et al.

(10) **Patent No.: US 7,527,873 B2**
(45) **Date of Patent: May 5, 2009**

(54) **THERMALLY AND ELECTRICALLY CONDUCTIVE INTERFACE**

(75) Inventors: **Sundaram Nand Kumar**, Schaumburg, IL (US); **Gary Sites**, Rancho Cucamonga, CA (US); **Bhavik Patel**, Bloomingdale, IL (US)

(73) Assignee: **American Standard Circuits**, Franklin Park, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 408 days.

(21) Appl. No.: **11/349,842**

(22) Filed: **Feb. 8, 2006**

(65) **Prior Publication Data**

US 2007/0184289 A1 Aug. 9, 2007

(51) **Int. Cl.**
B32B 9/04 (2006.01)
C08G 77/06 (2006.01)

(52) **U.S. Cl.** **428/447**; 528/24

(58) **Field of Classification Search** 165/185; 528/24

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,514,424	A *	5/1970	Brower et al.	....	524/448
3,840,492	A *	10/1974	Smith et al.	....	524/176
4,574,879	A	3/1986	DeGree et al.	....	165/185
4,602,125	A	7/1986	West et al.	....	174/138
4,602,678	A	7/1986	Fick	....	165/79
4,685,987	A	8/1987	Fick	....	156/247
4,810,563	A	3/1989	DeGree et al.	....	428/209
4,842,911	A	6/1989	Fick	....	428/40
4,852,646	A	8/1989	Dittmer	....	165/185
4,869,954	A	9/1989	Squitieri	....	428/283
4,907,124	A	3/1990	Kaufman	....	361/386
4,960,634	A	10/1990	Boyko et al.	....	428/220
5,213,868	A	5/1993	Liberty et al.	....	428/131
5,298,791	A *	3/1994	Liberty et al.	....	257/707
5,463,530	A	10/1995	DeGree	....	361/707
5,545,473	A	8/1996	Ameen et al.	....	428/283
5,591,034	A	1/1997	Ameen et al.	....	439/91
5,652,055	A	7/1997	King et al.	....	428/343
5,679,457	A *	10/1997	Bergerson	....	428/344

(Continued)

OTHER PUBLICATIONS

Encyclopedia of Polymer Science and Engineering, vol. 15, Scattering to Structural Foams (pp. 252-258 and cover page, 8 pages total), John Wiley and Sons, 1989.*

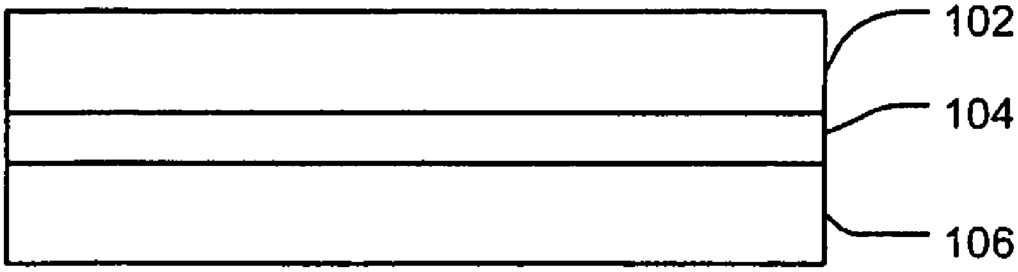
(Continued)

Primary Examiner—Randy Gulakowski
Assistant Examiner—Robert Loewe
(74) *Attorney, Agent, or Firm*—McDonnell Boehnen Hulbert & Berghoff LLP

(57) **ABSTRACT**

A thermally and electrically conductive material is provided as a mixture of a dimethylpolysiloxane, metal (or one metal coated with another metal) flakes and/or granules, a peroxide-based and/or a dimethyl hexane based catalyst, PTFE powder and a platinum based fire retardant. The thermally and electrically conductive material may be pre-formed into a film or pad and each side of the film protected with removable release layers. The thermally and electrically conductive material may alternatively be produced in a screen-printable paste. As such, a layer of the thermally and electrically conductive paste may be screen-printed on the metal surface in a complete sheet form or as a patterned film by using a stencil patterned screen mesh. Processes for manufacturing high- and low-frequency circuits that include the interface material are also provided.

5 Claims, 3 Drawing Sheets



U.S. PATENT DOCUMENTS

5,725,922	A *	3/1998	Nakamura et al.	428/36.9
5,738,936	A	4/1998	Hanrahan	428/313.5
5,766,740	A	6/1998	Olson	428/209
5,798,171	A	8/1998	Olson	428/220
6,054,198	A *	4/2000	Bunyan et al.	428/40.5
6,165,612	A *	12/2000	Misra	428/344
6,174,841	B1 *	1/2001	Yamada et al.	508/172
6,309,563	B1 *	10/2001	Iino et al.	252/514
6,384,171	B1 *	5/2002	Yamazaki et al.	528/15
6,414,078	B1 *	7/2002	Fukushima et al.	524/588
6,616,999	B1 *	9/2003	Freuler et al.	428/40.1
6,706,799	B2 *	3/2004	Igarashi et al.	524/495
6,734,250	B2 *	5/2004	Azechi et al.	524/588
6,783,692	B2 *	8/2004	Bhagwagar	252/70
6,799,628	B1	10/2004	Masseth et al.	165/80.4
6,852,573	B2 *	2/2005	Ebihara et al.	438/122
6,945,312	B2 *	9/2005	Czubarow et al.	165/80.3
2002/0092163	A1 *	7/2002	Fraivillig	29/847
2003/0047721	A1 *	3/2003	Igarashi et al.	252/502
2003/0096116	A1 *	5/2003	Mita et al.	428/408
2004/0043229	A1 *	3/2004	Aoki et al.	428/446
2004/0052998	A1 *	3/2004	Freuler et al.	428/40.1
2004/0055152	A1 *	3/2004	Fraivillig	29/830
2004/0094293	A1 *	5/2004	Mita et al.	165/185
2004/0254275	A1 *	12/2004	Fukui et al.	524/261
2005/0109766	A1 *	5/2005	Miller et al.	219/535
2005/0208251	A1 *	9/2005	Aisenbrey	428/40.1

OTHER PUBLICATIONS

Furnival, Courtney R., “Thermal and High Current Multilayer Printed Circuit Boards With Thermagon T-lam and Hybrid Boards”, Jan. 31, 2001.

“Thermally Conductive Insulators”, T-gon™ 200 Series.

“Sil-Pad® 400”, The Original Sil-Pad Material.

* cited by examiner

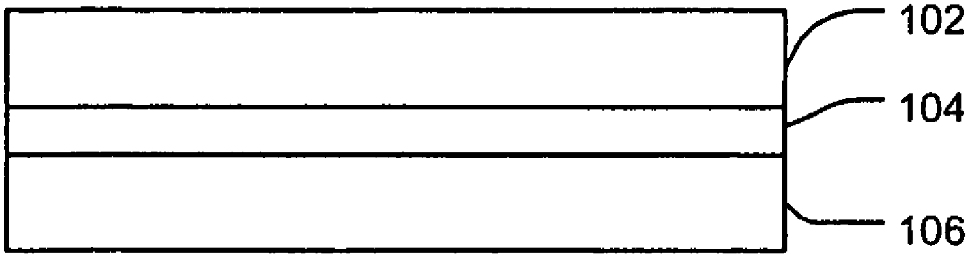


FIG. 1

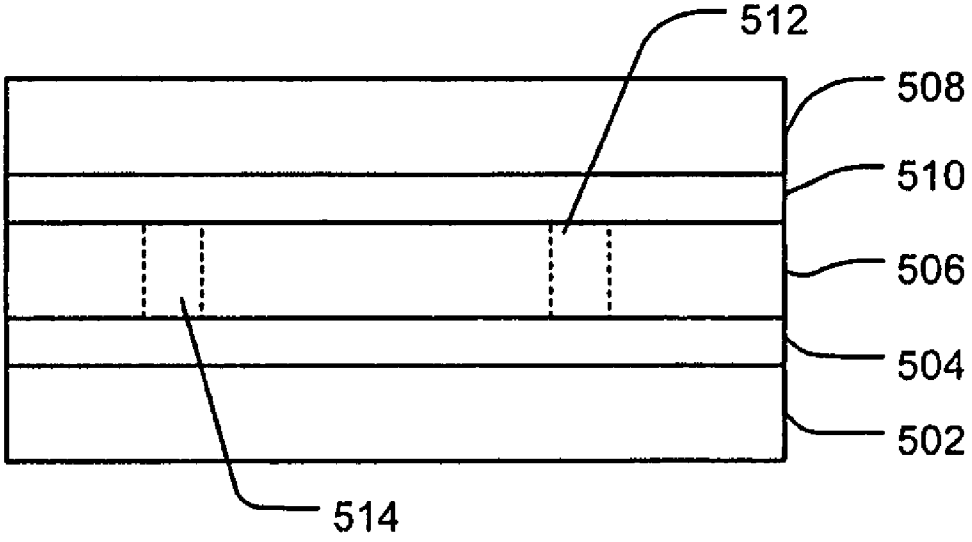


FIG. 5

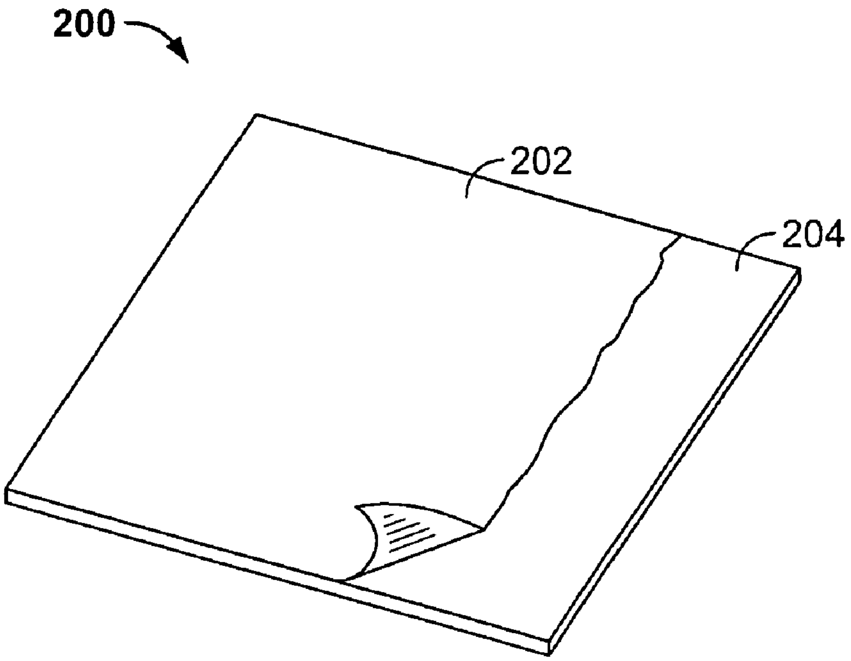


FIG. 2A

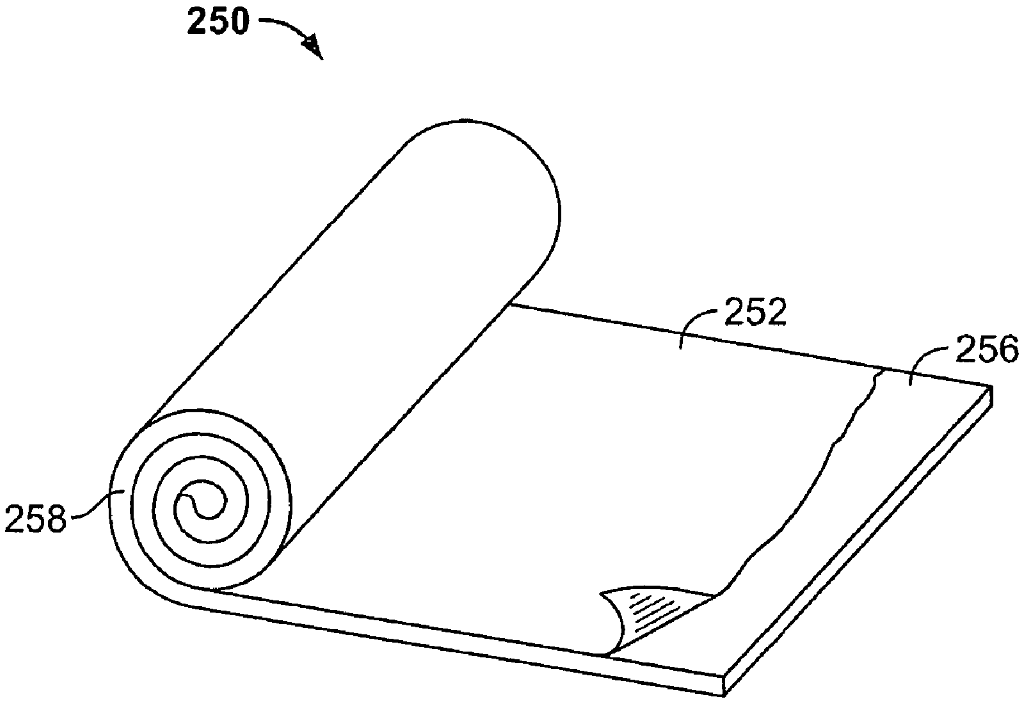


FIG. 2B

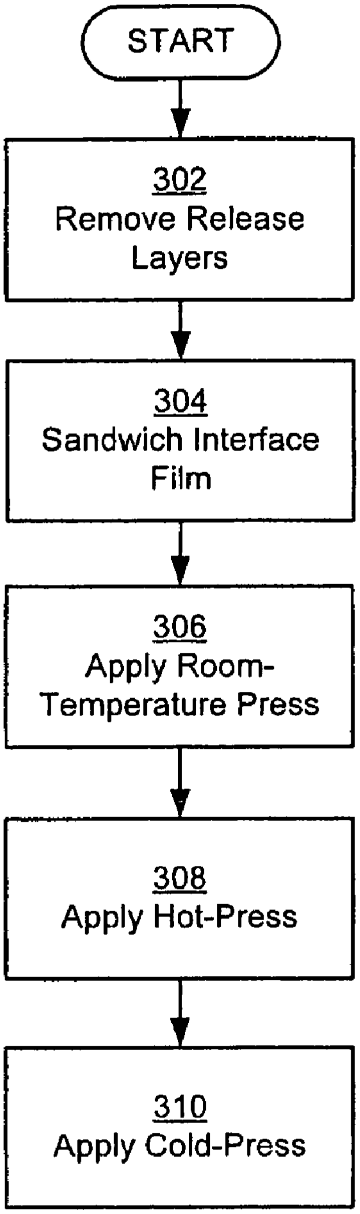

START
302
Remove Release Layers
304
Sandwich Interface Film
306
Apply Room-Temperature Press
308
Apply Hot-Press
310
Apply Cold-Press

FIG. 3

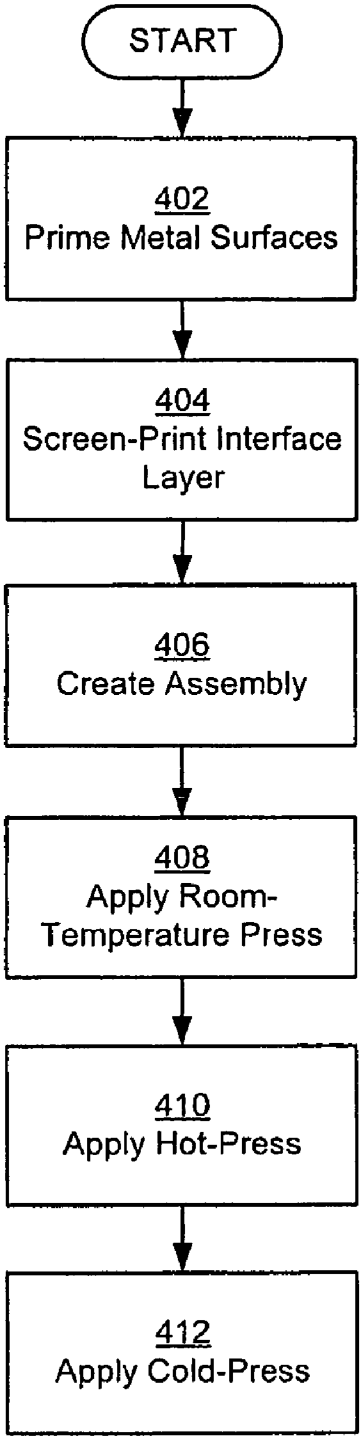

START
402
Prime Metal Surfaces
404
Screen-Print Interface Layer
406
Create Assembly
408
Apply Room-Temperature Press
410
Apply Hot-Press
412
Apply Cold-Press

FIG. 4

THERMALLY AND ELECTRICALLY CONDUCTIVE INTERFACE

FIELD OF THE INVENTION

The present invention relates to electrical interfacing in electronic devices and more specifically relates to using an interface material to bond a high or low frequency circuit board with a heat sink.

BACKGROUND

As electronic components become smaller and more powerful, their heat dissipation requirements also rise dramatically. With high or low frequency printed circuit board (PCB) assemblies when an aluminum heat sink is attached to a printed circuit board, an interface must be used that ensures a proper electrical connection. The interface may also serve as a thermal connector.

Historically, electrically (and thermally) conductive interface materials are mainly based on thermoset polymers, such as epoxy resins. Once a thermoset polymer is cured, it is inflexible. Thus, a major drawback of interface materials based on thermoset polymers is their inability to expand or contract with changes in the surrounding temperature. Also, epoxy resins usually have a lower temperature stability (up to about 400 F) as compared to silicones that can be used up to about 550 F. As a result, high power PCBs based on thermoset interfaces can exhibit weakening or even delamination at the circuit/heat sink interface if the interface temperature exceeds about 400 F due to the high heat generated during the performance of high power electronic components that are assembled over the PCB. There is a need, therefore, for an advancement in the art of preparing electrically and thermally conductive interface materials and in manufacturing circuit board assemblies using the interface material.

SUMMARY

The present invention is directed to an electrically and thermally conductive interface material and its application in a circuit board assembly. An electrically and thermally conductive interface material (“interface”) is provided as a mixture of a silicone-based compound, metal flakes and/or granules, flame retardant and a curing catalyst. The interface material may be pre-formed into a film or pad and each side of the film protected with removable release layers. Each side of the film may also include a coating of an adhesive material that aids in coupling the interface film with a metal surface. The interface material may alternatively be produced in a screen-printable paste. As such, a layer of the interface material paste may be screen-printed on the metal surface. The screen used for printing the paste on the metal surface can be either without any stencil pattern to allow the entire metal surface to be covered with the paste, or the screen can be mask patterned suitably to allow the paste applied in the corresponding pattern form on the metal surface.

The interface material is sandwiched between a printed circuit board and a heat sink to form the circuit board assembly. The interface film can be precut (e.g., by using a stencil to obtain complex film shapes), properly aligned and sandwiched between a printed circuit board and heat sink to form the assembly. In a multi-step press process for bonding, the assembly is cured and a laminate formed. The multi-step process includes a first pressure treatment applied to the assembly at room temperature to increase surface contact and to remove air pockets, a second pressure treatment applied to the assembly at a high temperature to cure the interface and create a laminate; and a third pressure treatment applied to the assembly at room temperature to controllably return the assembly to room temperature. The bonding process may also include a priming function that prepares metal surfaces of the circuit board and heat sink for receiving the interface material.

The interface material may also be applied in other formats, such as multi-layer circuits and to fill vias and channels in a circuit board. Further, the material may serve as an interface between a circuit component and a heat sink or other element.

It is expected that the invention will be useful in printed circuit board (PCB) assemblies that operate at various frequencies. These include high frequency applications such as those used in wireless communication systems (e.g., up to 40 GHz) and/or Radiofrequency (Rf) systems, as well systems that operate at much lower frequency.

The foregoing as well as other aspects, advantages, and alternatives will become apparent to those of ordinary skill in the art by reading the following detailed description and claims, with reference where appropriate to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a circuit board assembly according to an exemplary embodiment.

FIG. **2**(*a*) is a perspective view of an interface film in sheet form.

FIG. **2**(*b*) is a perspective view of an interface film in roll form.

FIG. **3** is a process flow of an exemplary embodiment of a manufacturing process of a circuit board assembly using pre-manufactured interface film.

FIG. **4** is a process flow of an exemplary embodiment of a manufacturing process of a circuit board assembly using the interface material in a screen-printable paste form.

FIG. **5** is a simplified schematic illustrating application of the interface material in a multilayer assembly.

DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT

1. Overview

Referring to the drawings, FIG. **1** is a diagram illustrating a circuit board assembly according to an exemplary embodiment. In the assembly, interface material **104** is sandwiched between a circuit board **102** and a heat sink **106**. In operation, excess heat generated by components mounted on the circuit board **102** may be shunted through interface material **104** to heat sink **106**.

Generally, the interface material **104** is composed of a silicone-based dielectric and metal flakes or granules. When cured in a hot-press method, the interface material **104** also provides a mechanical bond to help secure the assembly. An organic catalyst is included to aid in the curing process. A flame retardant is added to suppress any burning tendency.

The circuit board **102** is a printed (or printable) circuit board (PCB) on which electronic components may be mounted and may include a non-conducting substrate layer, such as a polytetrafluoroethylene (PTFE) and/or a fiberglass layer. In addition, the circuit board **102** preferably includes a metal base layer constructed of copper, for instance.

The heat sink **106** is a metal element, such as an aluminum, brass or copper element configured to receive a heat transfer along a planar side (or a side contoured to any other non planer shape of the ground plane of the PCB) and to release excess heat from its other surfaces. While the heat-sink may be configured as a simple rectangular block, other configurations that may add additional surface area may be appropriate.

In manufacture, the interface material **104** may be applied either as a screen-printable mixture or as a pre-formed laminate.

2. Silicone Based Electrically and Thermally Conductive Material

According to the exemplary embodiment, the electrically and thermally conductive interface is composed of a mixture having silicone-based compound as the primary ingredient. The silicone-based compound may, for instance be a dimethyl polysiloxane (DMPS), commercially available from sources such as, Dow Corning, General Electric, Wackers, etc. Beneficially, the silicone-based compound is easily obtainable and is more resistant to thermal shocks than other compounds such as an epoxy. Preferably, the silicone based compound is present in the interface mixture at a concentration of about 40% to about 75% of silicone base, by weight based on the total weight of the interface material.

Metal flakes and/or granules are included in the interface mixture to provide electrically and thermally conductive properties. Examples of the metal that may be used include silver, silver plated particles made up of other materials such as aluminum, etc. The currently preferred type is silver. The metal flakes and/or particles are about 100 to 300 micrometers (microns) in average diameter, and are present in the interface mixture at a concentration of about 20% to about 75%, preferably about 40% to about 75%, by weight (of metal) based on the total weight of the interface material.

A curing catalyst is included in the interface mixture to promote and/or control the curing reaction. The curing catalyst may also serve as a hardener. The catalyst is present in the interface mixture at a concentration of about 0.1% to about 10% by weight based on the total weight of the interface material. As is understood by those skilled in the art, other materials are added to the interface mixture to provide various functionalities. By way of example, the interface mixture may include one or more of the following components: up to about 5% by weight of the total weight of the interface mixture of benzoyl peroxide (as, e.g., a catalyst), up to about 5% by weight of the total weight of the interface mixture of PTFE, up to about 5% by weight based on the total weight of the interface mixture of 2,5-dimethylhexane, (which is the primary catalyst) and alumina trihydrate—platinum mixture as a fire retardant. The platinum-alumina trihydrate mixture may include between about 5.0% and 30.0%, by weight based on the total weight of the interface material. The platinum-alumina trihydrate mixture may include between about 0.1% and 2.0% platinum metal in alumina hydrate, by weight based on the total weight of the platinum-alumina trihydrate mixture itself.

3. Laminate Layer

In an exemplary embodiment, the interface material is pre-manufactured (pre-formed) film (laminate) that can be placed between the circuit board and the heat sink during assembly.

FIG. **2**(*a*) provides an exemplary embodiment of the interface film in a sheet form. As manufactured, a protected interface film **200** includes the interface film **204**, a first release layer **202** protecting a first side of the interface film **204** and a second release layer (not shown) protecting a second side of the interface film **204**. An embodiment provides sheets sized at approximately 10"×10"×6 mil. Another embodiment provides sheets sized at approximately 18"×12"×5 mil.

In operation, the release layers are removed to reveal the bare interface film **204** prior to placing the film within the circuit board assembly.

FIG. **2**(*b*) provides an exemplary embodiment of the interface film in a roll form. As manufactured a rolled protected interface film **250** includes the rolled interface film **256**, a first rolled release layer **252** protecting a first side of the rolled interface film **256** and a second release layer (not shown) protecting a second side of the rolled interface film **256**. A roll **258** allows a large amount of interface film to be stored without unduly bending or crimping the film. In operation, a portion of the rolled protected interface film **250** may be unrolled and cut according to manufacturing needs. As used herein, the term "interface film" includes, but is not limited to, the sheet form and the rolled form.

In the exemplary embodiment, the mixture as described provides adhesive properties. However, in a further embodiment, an adhesive is included with the interface film to promote bonding with the metal surfaces of the heat sink and circuit board. In one application, the adhesive is added to the surface of both sides of the interface film prior to application of the release layer. In an alternative application, the adhesive is added to the interface mixture prior to forming it as a film.

4. Lamination Process

FIG. **3** provides an exemplary process flow for manufacturing the circuit board assembly with the pre-manufactured interface film. At **302**, the release layers are removed from each side of the interface film to expose the film. At **304**, the interface film is then sandwiched between the circuit board and the heat sink. Although FIG. **3** shows function **302** occurring prior to function **304**, an embodiment provides that these steps are executed in an intertwined function. The intertwined function may include removing a first release layer from a first side of the interface film, then pressing the exposed side against a planar side of the heat sink. Once the interface film is (loosely) attached to the heat sink, the second release layer is removed to expose a second side of the interface film. The circuit board is then pressed against the second side to form the sandwich assembly shown in FIG. **1**. Of course, in another embodiment, the intertwined function may be reversed so that the interface film is first attached to the circuit board and then attached to the heat sink. At this point, surfaces of the interface film are pliable and are configured to allow a high rate of surface contact.

Once the sandwich assembly is formed, at **306**, a room-temperature pressure treatment is applied to the assembly—pressing the heat sink toward the circuit board. In operation, it is expected that this pressure treatment may be applied using a roller-assembly or other mechanisms. The room-temperature pressure treatment ideally works to (i) substantially remove any air-pockets that could reduce thermal conductivity and create 'hot spots' in the assembly and (ii) increase surface contact at the circuit board/film boundary as well as the heat sink/film boundary.

At **308**, a high-temperate pressure treatment is applied to the assembly—again pressing the heat sink toward the circuit board. The high-temperature press is intended to promote curing of the interface film as well as bonding of the interface film to the adjacent metal. Typically, the high-temperature bonding may occur at a temperature of approximately 330 degrees Fahrenheit and a pressure of approximately 480 PSI for approximately 20 minutes. Of course, these parameters may vary according to a number of factors, such as the thickness and composition of the interface layer and the particular requirements of any curing catalyst used, for instance. In a further embodiment, the high-temperature pressure treatment includes application of a temperature of at least 320 degrees Fahrenheit and pressure of at least 500 PSI for at least 20 minutes.

At **310**, a low-temperature pressure treatment is applied to the assembly—again pressing the heat sink toward the circuit board. According to the exemplary embodiment, the low-temperature pressure treatment is applied immediately following the high-temperature pressure treatment. The low-temperature may be room-temperature or another value at or below room temperature. In a further embodiment, the low-temperature is not a fixed temperature, but is a temperature that is reduced over time during the low-temperature pressure treatment.

In the high-temperature pressure treatment, the silicone matrix forms cross-links that are hardened/cured. The low-temperature pressure treatment cools the interface down to room temperature under pressure without letting any air trap between the bonded layers. This may be necessary to avoid delamination of the bonded layers. Once the assembly is cooled and properly cleaned to remove deleterious foreign materials, circuit components may be assembled on the circuit board. According to the exemplary embodiment, the low-temperature first pressure treatment is accomplished at a pressure of approximately 75 PSI for approximately 1 minute.

In a further embodiment, the circuit board has a metal base (such as a copper) that is attached directly to the interface film. Likewise, a planar surface of the heat sink is the portion attached to the other side of the interface film.

Prior to attaching the circuit board and heat sink to the interface film, it may be appropriate to prepare the metal surfaces—thus helping to ensure better adhesion to the film. The preparation may include, for instance, degreasing, chemical cleaning, desmutting, physical roughening of the metal surface, cleaning the surface with alcohol and applying a thin coat of a primer material. This conditions the bondable metal surfaces for better adhesion with the silicone material.

In a further embodiment, the outer surface of the aluminum surface may be given a surface finish of nickel and/or gold.

In another embodiment, anodizing the planar surface of the heat sink may serve to prepare the surface for binding with the interface film.

In an exemplary embodiment, the end result of the lamination process is that the circuit board assembly becomes a single element—the interface film bonded securely with both the metal bottom of the PCB and the planar surface of the heat sink. In some cases, excess interface material from an edge of the assembly may be trimmed.

5. Screen-Printing Process

In another exemplary embodiment, the thermally and electrically conductive mixture is provided in a screen-printable paste form. The screen printable form may provide a lower cost mechanism for creating a thermally and electrically conductive interface between the circuit board and the heat sink.

FIG. **4** provides an exemplary process flow for manufacturing the circuit board assembly with the thermally and electrically conductive mixture in screen-printable paste form. At **402**, the metal surfaces of the circuit board and heat sink are cleaned and primed. As described above, this may include degreasing, chemical cleaning, desmutting, and physical roughening of the metal surface and then cleaning the surface with alcohol and applying a thin coat of a primer material.

At **404** an interface layer is screen printed onto one of the metal surfaces. According to various embodiments, either the metal base of the printed circuit board or the planar surface of the heat sink receives the screen printed layer. The screen printing may be adjusted to apply various layer thicknesses and pattern according to manufacturing specifications; in addition, the screen printing may be patterned to avoid artifacts in the circuit board such as vias and posts, for instance. The screen patterning technique includes stencil formation of required pattern on the screen. In a further embodiment, the screen-printing step is repeated until the interface layer is of a desired thickness. The screen printing can be performed manually or by a screen printing machine.

At **406** the interface layer is then sandwiched between the circuit board and the heat sink to create the assembly.

Once the sandwich assembly is formed, at **408**, a room-temperature pressure treatment is applied to the assembly—pressing the heat sink toward the circuit board. In operation, it is expected that this room-temperature pressure treatment may be applied using a roller-assembly or other mechanisms (as may the other pressure treatments). The room-temperature pressure treatment ideally works to (i) substantially remove any air-pockets that could reduce thermal conductivity and create ‘hot spots’ in the assembly and (ii) increase surface contact at the circuit board/film boundary as well as the heat sink/film boundary. Of course, the room temperature press may provide other benefits.

At **410**, a high-temperate pressure treatment is applied to the assembly—again pressing the heat sink toward the circuit board. The high-temperature press is intended to promote curing of the interface film as well as bonding of the interface film to the adjacent metal. Typically, the high-temperature bonding may be performed at a temperature of approximately 330 degrees Fahrenheit and a pressure of approximately 480 PSI for a duration of approximately 20 minutes. Of course, these parameters may vary according to a number of factors, such as the thickness and composition of the interface layer and the particular requirements of any curing catalyst used, for instance. In a further embodiment, the high-temperature pressure treatment includes application of a temperature of at least 320 degrees Fahrenheit and a pressure of at least 500 PSI for a duration of at least 20 minutes.

At **412**, a low-temperature pressure treatment is applied to the assembly—again pressing the heat sink towards the circuit board. According to the exemplary embodiment, the low-temperature pressure treatment is applied immediately following the high-temperature pressure treatment. According to the exemplary embodiment, the low-temperature pressure treatment is accomplished at approximately 200 PSI for approximately for 10 minutes or until the assembly is properly cooled.

6. Alternative Embodiments

Of course, the silicone-based interface as described may be useful in more arenas than those specifically described in the examples above. For instance, FIG. **5** shows a multilayer circuit board using the interface. A multilayer printed circuit board may have multiple layers **508**, **506** that are separated by a first interface **510**. Thermal vias **514**, **512** may thermally couple the first interface **510** with a second interface **504**. Of course, there could be more circuit layers accompanied with corresponding conducting interface material locations, with the interface material serving as a conduit of heat and current to the sink. The second interface **504** being coupled with a heat sink **502**.

In the embodiment of FIG. **5**, the interface layers **504**, **510** may be either pre-manufactured interface films or screen-printed interface layers. Filling the vias **514**, **512** may be accomplished via screen-printing, injection, or other mechanical methods, for instance. Of course, FIG. **5** is a simplified embodiment. A working embodiment may include a greater number of thermal vias as well as more circuit board layers. The interface may also be useful to fill thermal channels that, for instance, shunt waste heat to an edge of the circuit board. The thermal channels may be filled in a similar fashion as the thermal vias. In a double-sided circuit board, the interface may also be used to shunt waste heat to a heat sink.

In yet another embodiment, the thermally and electrically conductive material may be used to couple an electronic component directly to a heat sink. For instance, the interface may be used to couple a processor, a LED device, an electric motor, or a power source directly with a heat sink.

7. Material Properties

Typical data for a six mil thick silicone interface film is provided in Table 1. The results shown in Table 1 are a summary of data obtained from test results performed on a preformed electrically and thermally conductive layer constructed in accordance with an exemplary embodiment.

TABLE 1

Test Method	Property	Value
ASTM D3767	Thickness	6 mil.
ASTM D412	Tensile Strength	>200 PSI
ASTM D2240	Hardness (Shore A)	80-90
ASTM D412	Elongation	>200%
	Tear Strength	>60 PPI
ASTM D5470	Thermal Conductivity	0.6 to 25.0 W/m-K
MIL G 83528	Electrical Resistivity	0.0007 ohmcm

Of course, other embodiments may be constructed to achieve alternative results. For instance, an interface film may be manufactured with any thickness ranging from 5 mil upwards According to a preferred embodiment, it is important to maintain a substantially uniform thickness across a manufactured film in order to ensure a strong bond with the circuit board and heat sink.

CONCLUSION

A set of exemplary embodiments of the present invention has been described above. Those skilled in the art will understand, however, that changes and modifications may be made to these embodiments without departing from the true scope and spirit of the present invention, which is defined by the claims. For instance, in the process flow descriptions, certain steps may be removed or modified or eliminated without destroying utility of the process as a whole. Likewise, descriptions of the use of the interface material should not be seen to limit their use to those embodiments alone.

We claim:

1. An interface film comprising: an interface material comprising a dimethylpolysiloxane, metal, or one metal coated with another metal, flakes and/or granules, a platinum-based fire retardant and a peroxide based catalyst; a first release layer protecting a first side of the interface material; and a second release layer protecting a second side of the interface material and wherein the interface material includes benzoyl peroxide, 2,5-dimethylhexane, and PTFE powder.

2. The interface film of claim **1** wherein the dimethylpolysiloxane comprises between about 40% to 75%, by weight based on the total weight of the interface material, the metal flakes and/or granules comprise between about 20% to 75%, by weight based on the total weight of the interface material.

3. The interface film of claim **2** wherein the peroxide based catalyst is benzoyl peroxide, which comprises between about 0.1% and 5.0%, by weight based on the total weight of the interface material, the 2,5-dimethylhexane comprises between 0.1% and 5.0%, by weight based on the total weight of the interface material, and the PTFE powder comprises between about 0.1 and 5.0%, by weight based on the total weight of the interface material.

4. The interface film of claim **2** wherein the platinum-based fire retardant comprises: a platinum-alumina trihydrate mixture wherein the platinum-alumina trihydrate mixture includes between about 5.0% and 30.0%, by weight based on the total weight of the interface material.

5. The interface film of claim **4**, wherein the platinum-alumina trihydrate mixture includes between about 0.1% and 2.0% platinum metal in alumina hydrate, by weight based on the total weight of the platinum-alumina trihydrate mixture.

* * * * *